

PATENT ABSTRACTS OF JAPAN

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(21)Application number : 07-347668

(71)Applicant : SANO FUJI KOKI KK

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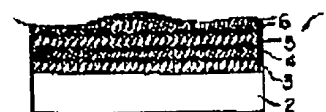
(72)Inventor : KAWAMURA NOBUJI

(54) DOUBLE REFRACTIVE FILM AND OPTICAL SYSTEM USING THE SAME

(57)Abstract:

PROBLEM TO BE SOLVED: To make it possible to enhance the degree of freedom in designing an optical system when a double refractive film formed with diagonally vapor deposited films by alternately laminating diagonally vapor deposited single layer films consisting of dielectric materials different from each other in the diagonally vapor deposited film is used for the optical system.

SOLUTION: The double refractive plate 1 is constituted by alternately forming the single layer films 3, 5 consisting of TiO₂ (titanium dioxide) and the single layer films 4, 6 consisting of SiO₂ (silicon oxide) by diagonal vapor deposition on a transparent glass substrate 2. The respective single layer films 3, 4, 5, 6, are set at approximately $\lambda/4$ ($\lambda=650\text{nm}$) in the films thickness. The double refractive plate 1 is formed by a vapor deposition apparatus. In such a case the TiO₂ and SiO₂ are used as the dielectric materials. Any dielectric materials which are basically transparent to the light to be used and with which the desired double refraction quantity is obtainable by the combinations of the materials are usable as the dielectric materials. For example, metal oxides, such as Ta₂O₅, Al₂O₃, WO₃, Y₂O₃, Bi₂O₃, Nb₂O₅, ZnS, MoO₃, etc., are usable.



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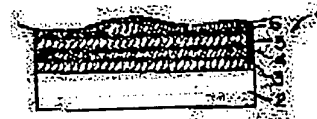
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 CLAIMS

[Claim(s)]

[Claim 1] It is the birefringent plate which carries out the laminating of the slanting vacuum evaporationo monolayer which consists of dielectric materials from which this slanting vacuum evaporationo film differs mutually in the birefringent plate which carries out the vacuum evaporationo of the dielectric materials from across, and comes to form a slanting vacuum evaporationo film on the front face of a vacuum evaporationo-ed substrate by turns, and is characterized by the bird clapper.

[Claim 2] The birefringent plate according to claim 1 characterized by making into the abbreviation same direction the optical axis of all the slanting vacuum evaporationo monolayers that constitute the aforementioned slanting vacuum evaporationo film.

[Claim 3] Optical system using the birefringent plate which arranges a birefringent plate and is characterized by the bird clapper so that it may have the predetermined amount of birefringences and the plane of incidence and the aforementioned optical axis of a light beam which carry out incidence to this birefringent plate may serve as a predetermined angular relation-ship, after the light beam irradiated by this birefringent plate is injected from this birefringent plate in the optical system using the birefringent plate of a claim 2.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] this invention relates to the birefringent plate in which the slanting vacuum evaporatio film used for various optical instruments was formed, and the optical system using this birefringent plate.

[0002]

[Description of the Prior Art] Conventionally, the birefringent plate in which the slanting vacuum evaporatio film of dielectric materials was formed on the substrate front face is known. By making a substrate front face incline to the coming-flying direction of vacuum evaporatio material (dielectric materials), arranging, and forming a vacuum evaporatio film as a columnar structure which grows in the direction of slant from a substrate front face, this makes the birefringence operation to an incident light give this vacuum evaporatio film, for example, is used for it as optical functional devices, such as a polarization beam splitter and a phase plate.

[0003]

[Problem(s) to be Solved by the Invention] By the way, in the **** birefringent plate mentioned above, it was difficult to control the phase contrast between the rectangular polarization components of the light which carries out incidence to this birefringent plate free. When following, for example, using the above-mentioned birefringent plate as a phase plate, it was difficult to acquire arbitrary phase contrast. Moreover, when using the above-mentioned birefringent plate as a beam splitter of a tabular, since the amount of birefringences was small, it was difficult [it] to design so that incidence of the light beam may be carried out with a small incident angle.

[0004] this invention is made in view of such a situation, and when using the birefringent plate in which it comes to form a slanting vacuum evaporatio film as various optical elements in an optical system, it aims at offering the optical system using the birefringent plate and this which can raise the flexibility of a design of the optical system.

[0005]

[Means for Solving the Problem] The birefringent plate of this invention carries out the vacuum evaporatio of the dielectric materials from across on the front face of a vacuum evaporatio-ed substrate, and in the birefringent plate which comes to form a slanting vacuum evaporatio film, this slanting vacuum evaporatio film carries out the laminating of the slanting vacuum evaporatio monolayer which consists of mutually different dielectric materials by turns, and is characterized by the bird clapper. Moreover, it is desirable to make into the abbreviation same direction the optical axis of all the slanting vacuum evaporatio monolayers that constitute the aforementioned slanting vacuum evaporatio film.

[0006] Furthermore, the optical system using the birefringent plate of this invention So that the optical axis of all the slanting vacuum evaporatio monolayers that constitute the aforementioned slanting vacuum evaporatio film is the above-mentioned birefringent plate made into the abbreviation same direction, and it may have the predetermined amount of birefringences, after the light beam irradiated by this birefringent plate is injected from this birefringent plate A birefringent plate is arranged and it is characterized by the bird clapper so that the plane of incidence and the aforementioned optical axis of a light beam which carry out incidence to this birefringent plate may serve as a predetermined angular relation-ship. In addition, the above "alternation" shall mean two kinds of not only monolayers but the state of accumulating three or more kinds of monolayers in order.

[0007]

[Embodiments of the Invention] Hereafter, it explains, referring to a drawing about 1 operation form of this invention.

Drawing 1 is the schematic diagram showing the birefringent plate of 1 operation form of this invention. In addition, in drawing 1, the scale of the direction of a laminating is drawn on a different scale from an actual scale. This birefringent plate 1 comes to form the monolayers 3 and 5 of TiO₂ (titanium dioxide), and the monolayers 4 and 6 of SiO₂ (silicon oxide) by slanting vacuum evaporatio by turns on the transparent glass substrate 2. In addition, it is possible to use the substrate which replaces with this transparent glass substrate and consists of various material.

[0008] Although omitted and drawn in drawing 1, the laminating of a large number, for example, the monolayer of 22 layers, is carried out in fact. Moreover, the thickness of each monolayers 3, 4, 5, and 6 is set as abbreviation $\lambda / 4$ ($\lambda = 650\text{nm}$). The birefringent plate 1 shown in this drawing 1 is formed by the **** vacuum evaporatio equipment shown in drawing 2 (A).

[0009] The bell jar 11 exhausted by the vacuum in the interior with the exhaust air pump which does not illustrate this vacuum evaporatio equipment, The evaporation source 12 for evaporating the vacuum evaporatio material 12A and 12B of TiO₂ and SiO₂, The electron gun 13 which injects electron beam 13A for heating each vacuum evaporatio material 12A and 12B of this evaporation source 12, It has the dome-like work 15 grade which carries out setting maintenance of two or more substrates 16 at the predetermined angular position so that the vacuum evaporatio style 14 which evaporated from the evaporation source 12 may carry out incidence aslant to the front face of a substrate 16. Rotation of this dome-like work 15 is enabled at predetermined speed in the predetermined direction by the rotary motor which is not illustrated, and equalization of thickness is attained between the substrates 16 held by this and on each substrate 16. In

addition, the evaporation source 12 is arranged near the axis-of-rotation lower part of this dome-like work 15. [0010] Moreover, drawing 2 (B) is drawing which looked at the dome-like work 15 of drawing 2 (A) from the upper part. Each substrate 16 is attached in the wall section of a dome by the predetermined substrate electrode holder which is not illustrated. In addition, in this view, although a part of substrate 16 held is drawn, in fact, in the direction of a perimeter enclosure, many substrates 16 are arranged, and it is made and held from a center position. moreover, although especially the incident angle α to substrate 16 front face of the above-mentioned vacuum evaporation style 14 (angle; which the normal of a substrate 16 and the perpendicular direction make in practice – below the same) is not limited, it is possible to prevent nebula-ization of a vacuum evaporation film, making 45 degrees - about 65 degrees, then the amount of birefringences (difference Δn of the refractive index n_o to Tsunemitsu, and the refractive index n_e to unusual light) into a large value by the average

[0011] In addition, although TiO_2 and SiO_2 are used as dielectric materials with the above-mentioned operation gestalt As dielectric materials used by this invention, are transparent to the light used fundamentally. And the metallic oxide of Ta 2O_5 , aluminum 2O_3 , WO_3 , Y_2O_3 , Bi_2O_3 , Nb_2O_5 , ZnS , MoO_3 , CeO_2 and SiO , and SnO_2 grade can be used that the desired amount of birefringences should just be obtained with the combination of the material. Moreover, it is desirable to consider as the thickness which is the grade a columnar structure can fully grow up to be about each class, although it is possible for it not to be restricted to the thing of the above-mentioned example as thickness of a vacuum evaporation film, and to consider as various thickness, for example, it is dozens of nm. Considering as the above is desirable.

[0012] Moreover, it is also possible for three or more kinds of monolayers to be repeated in order, and to be made to carry out a laminating. moreover, an optical axis [in / each vacuum evaporation films 3, 4, 5, and 6 / on one birefringent plate 16 and] – an abbreviation arranging **** cage -- In case this birefringent plate 16 is used, by adjusting appropriately the direction of this optical axis, the angular relation-ship of optical plane of incidence, and the value of an incident angle θ It is possible to obtain the optical system which can be made into the value of a request of the phase contrast between the polarization components with which can obtain desired polarization permeability and a polarization reflection factor, and components and an incident light cross at right angles.

[0013]

[Example] Hereafter, a concrete example is explained.

[0014] The incident angle α to the substrate 16 of the <example 1> vacuum evaporation style 14 was set as 60 degrees, and thickness carried out the 22-layer laminating of the mutual layer of TiO_2 and SiO_2 set as $\lambda/4$ ($\lambda = 650\text{nm}$) on the transparent glass substrate 2 to the light, and formed the polarization beam splitter 20. Next, to the membrane formation front face of this polarization beam splitter 20, incidence of the light beam was carried out so that the degree θ of incident angle of a light beam might become 45 degrees, and so that optical plane of incidence and an optical axis might become parallel (drawing 3 (A)). In addition, the right figure of drawing 3 (A) is a side elevation when seeing from [in the left figure of drawing 3 (A)] arrow A. The light transmittance T_p of P component at this time, and light transmittance T_s of S component The spectral characteristic is shown in drawing 3 (B).

[0015] To the membrane formation front face of the polarization beam splitter 20 formed like the <example 2> above-mentioned example 1, incidence of the light beam was carried out so that the degree θ of incident angle of a light beam might become 45 degrees, and so that optical plane of incidence and an optical axis might intersect perpendicularly (drawing 4 (A)). In addition, the right figure of drawing 4 (A) is a side elevation when seeing from [in the left figure of drawing 4 (A)] arrow A. The light transmittance T_p of P component at this time, and light transmittance T_s of S component The spectral characteristic is shown in drawing 4 (B).

[0016] To the membrane formation front face of the polarization beam splitter 20 formed like the <example 3> above-mentioned example 1, incidence of the light beam was carried out so that the degree θ of incident angle of a light beam might become 0 degree (drawing 5 (A)). In addition, the right figure of drawing 5 (A) is a side elevation when seeing from [in the left figure of drawing 5 (A)] arrow A. The spectral characteristic of the polarization permeability T_o in the direction of Tsunemitsu at this time and the polarization permeability T_e in the direction of unusual light is shown in drawing 5 (B). Moreover, the value of reflective phase $\Delta\theta_o$ in the direction of Tsunemitsu at this time and reflective phase $\Delta\theta_e$ in the direction of unusual light is shown in drawing 6 (B). in addition, the optical-element arrangement shown in drawing 6 (A), and T_o and T_e of drawing 6 (B) The optical-element arrangement which shows the graph which shows the spectral characteristic – characteristic to each drawing 5 (A), and T_o and T_e of drawing 5 (B) the graph which shows the spectral characteristic – substantial – abbreviation – it is the same Moreover, drawing 7 is a graph which shows the wavelength dependency of the two above-mentioned differences, reflective phase $\Delta\theta_o$ and $\Delta\theta_e$.

[0017] The incident angle α to the substrate 16 of the <example of comparison> vacuum evaporation style 14 was set as 0 degree, the 22-layer laminating of the mutual layer of TiO_2 and SiO_2 in which thickness was set as $\lambda/4$ ($\lambda = 650\text{nm}$) was carried out on the transparent glass substrate 2 to the light, and beam-splitter 20A which does not have form birefringence was formed. To the membrane formation front face of this beam-splitter 20A, incidence of the light beam was carried out so that the degree θ of incident angle of a light beam might become 45 degrees (drawing 8 (A)). In addition, the right figure of drawing 8 (A) is a side elevation when seeing from [in the left figure of drawing 8 (A)] arrow A. The light transmittance T_p of P component at this time, and light transmittance T_s of S component The spectral characteristic is shown in drawing 8 (B).

[0018] They are T_p and T_s so that clearly also from the graph which shows those spectral characteristics for the thing of the above-mentioned example 1 and an example 2 compared with the thing of the example of comparison. The interval of standup wavelength is narrow. Moreover, since it does not have a polarization property when it considers as the incident angle of $\theta = 0$ degree, it is clear that the things of an example 3 differ greatly compared with this what does not have form birefringence.

[0019] In addition, it sets to drawing 6 and drawing 7, and they are reflective phase $\Delta\theta_o$ and $\Delta\theta_e$. Although the related numeric value is shown, it is possible (refer to drawing 10) for the phase of transparency to be shown similarly, of course, and, thereby, the flexibility of a design of optical system becomes large. Furthermore, when an incident angle θ becomes

except 0 degree, optical system can be designed, also taking phase δ_P of P component, and phase δ_S of S component into consideration.

[0020] The incident angle α to the substrate 16 of the <example 4> vacuum evaporation style 14 is set as 60 degrees. Thickness the mutual layer of TiO_2 (amount δ_n of birefringences 0.075), and Ta_2O_5 (amount δ_n of birefringences 0.065) set up as shown in the following table 1 To the light, the 35-layer laminating was carried out on the transparent glass substrate 2, the best layer which consists of SiO_2 (amount δ_n of birefringences 0) to which thickness was further set as shown in the following table 1 was formed, and phase plate 20B was produced. all the thickness at this time – 2.064nm it was . It arranges, as this phase plate 20B is shown in drawing 9 (A), and wavelength λ_0 is 600nm. Incidence of the light beam was carried out so that an incident angle θ might become 0 degree to the membrane formation front face of this phase plate 20B about a light beam (drawing 9 (A)). In addition, the right figure of drawing 9 (A) is a side elevation when seeing from [in the left figure of drawing 9 (A)] arrow A.

[0021] Phase plate 20B arranged by such state is wavelength λ_0 . 600nm 88 degrees of phases of the polarization component which intersects perpendicularly can be mutually shifted to a light beam, and it functions as $\lambda/4$ board. The spectral characteristic of the polarization permeability T_o in the direction of Tsunemitsu at this time and the polarization permeability T_e in the direction of unusual light is shown in drawing 9 (B). Moreover, transparency phase δ_{λ_0} in the direction of Tsunemitsu at this time Transparency phase δ_{λ_0} in the direction of unusual light The graph showing the wavelength dependency of a difference is shown in drawing 10 . The concrete film composition of this example is shown in the following table 1.

[0022]

[Table 1]

膜 No.	材料	屈折率 n_0	膜厚 d (nm)	$4 n_0 d / \lambda_0$
	空気	1. 0		1. 0 4 5
1	SiO ₂	1. 4 6	8 9. 5	0. 7 2 7
2	TiO ₂	2. 3	8 9. 5	0. 8 0 0
3	Ta ₂ O ₅	2. 0	5 0. 0	0. 9 0 0
4	TiO ₂	2. 3	4 8. 9	1. 0 0 0
5	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
6	TiO ₂	2. 3	5 4. 3	1. 0 0 0
7	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
8	TiO ₂	2. 3	5 4. 3	1. 0 0 0
9	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
10	TiO ₂	2. 3	5 4. 3	1. 0 0 0
11	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
12	TiO ₂	2. 3	5 4. 3	1. 0 0 0
13	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
14	TiO ₂	2. 3	5 4. 3	1. 0 0 0
15	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
16	TiO ₂	2. 3	5 4. 3	1. 0 0 0
17	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
18	TiO ₂	2. 3	5 4. 3	1. 0 0 0
19	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
20	TiO ₂	2. 3	5 4. 3	1. 0 0 0
21	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
22	TiO ₂	2. 3	5 4. 3	1. 0 0 0
23	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
24	TiO ₂	2. 3	5 4. 3	1. 0 0 0
25	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
26	TiO ₂	2. 3	5 4. 3	1. 0 0 0
27	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
28	TiO ₂	2. 3	5 4. 3	1. 0 0 0
29	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
30	TiO ₂	2. 3	5 4. 3	1. 0 0 0
31	Ta ₂ O ₅	2. 0	6 2. 5	1. 0 0 0
32	TiO ₂	2. 3	6 2. 5	1. 0 0 0
33	Ta ₂ O ₅	2. 0	4 8. 9	0. 9 0 0
34	TiO ₂	2. 3	5 0. 0	0. 8 0 0
35	Ta ₂ O ₅	2. 0	3 9. 5	0. 7 2 7
36	TiO ₂	2. 3	約 2 0 6 4	
全膜厚		1. 5 1		
ガラス基板 (BK7)				

但し、 $\lambda_0 = 500 \text{ nm}$

[0023]

[Effect of the Invention] As explained above, according to the birefringent plate of this invention, and the optical system using this, the slanting vacuum evaporation of two or more kinds of monolayers is carried out by turns, and the slanting vacuum evaporation film is formed. Therefore, by making into a parameter the dielectric materials, the optical thickness of each monolayer, and the number of layers which form each monolayer, since the thing of the desired amount of birefringences can be obtained, the design flexibility of an optical element can be raised. Moreover, in case every ***** and this optical element are used for the direction of the optical axis of each monolayer, the design flexibility of optical ****, as a result an optical system can be further raised by choosing appropriately the angular relation-ship of a direction and optical plane of incidence and the degree of incident angle of this optical axis.

[0024] For example, in the conventional polarization beam splitter, although the beam splitter of a tabular could not be used but the glass-block type beam splitter had to be used when a light beam carried out incidence with a small incident angle, it becomes possible by applying the thing of this invention to separate certainly 2 polarization components which intersect perpendicularly by the beam splitter of a tabular also to the light beam of a small incident angle. Moreover, since it can also

consider as the design which gives the function as a phase plate to this beam splitter, in a beam splitter, the phase plate (for example, $\lambda/4$ board, $\lambda/2$ board) which might be formed on one optical path of the latter part becomes unnecessary conventionally.

[0025] Moreover, in case the polarization component which supported each sexual desire news with the dichroic prism of an electrochromatic display video projector is compounded, [for example,] Since it started by the spectral characteristic of each [these] polarization component and the big gap has arisen in the value of wavelength, although the spectral characteristic after composition will be stair-like in the conventional thing Since the value of the wavelength of the standup in the spectral characteristic of the two above-mentioned polarization components can be set as a very near value by applying this invention, when these two polarization components are compounded, it is possible to prevent that the synthetic spectral characteristic becomes stair-like. In addition, it is also possible to change the spectral characteristic of another side and to extend both interval, without changing one spectral characteristic between the two above-mentioned polarization components.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The schematic diagram showing the lamination of the birefringent plate concerning the operation gestalt of this invention

[Drawing 2] The schematic diagram showing an example of the vacuum evaporationo equipment which forms the slanting vacuum evaporationo film of a birefringent plate shown in drawing 1

[Drawing 3] The graph which shows the optical-element plot plan (A) and light-transmittance property of an example 1 (B)

[Drawing 4] The graph which shows the optical-element plot plan (A) and light-transmittance property of an example 2 (B)

[Drawing 5] The graph which shows the optical-element plot plan (A) and light-transmittance property of an example 3 (B)

[Drawing 6] The graph which shows the optical-element plot plan (A), and a light-transmittance property and a reflective phase of an example 3 (B)

[Drawing 7] The graph which shows the difference of the reflective phase in an example 3

[Drawing 8] The graph which shows the optical-element plot plan (A) and light-transmittance property of the example of comparison (B)

[Drawing 9] The graph which shows the optical-element plot plan (A) and light-transmittance property of an example 4 (B)

[Drawing 10] The graph which shows the difference of the transparency phase in an example 4

[Description of Notations]

1 Birefringent Plate

2 Transparent Glass Substrate

3, 4, 5, 6 Monolayer

11 Bell Jar

12 Evaporation Source

12A, 12B Vacuum evaporationo material

13 Electron Gun

13A Electron beam

14 Vacuum Evaporationo Style

15 Dome-like Work

16 Substrate

20 20A Beam splitter

20B Phase plate

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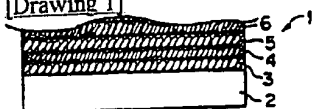
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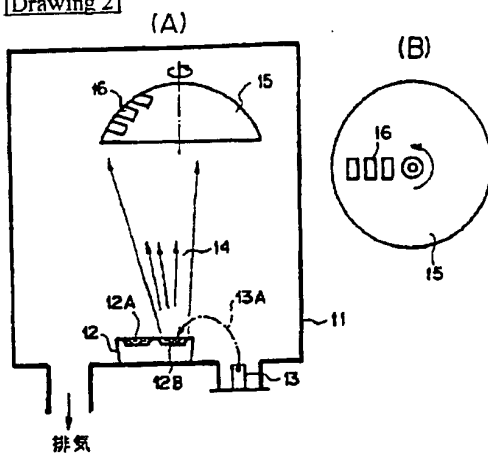
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DRAWINGS

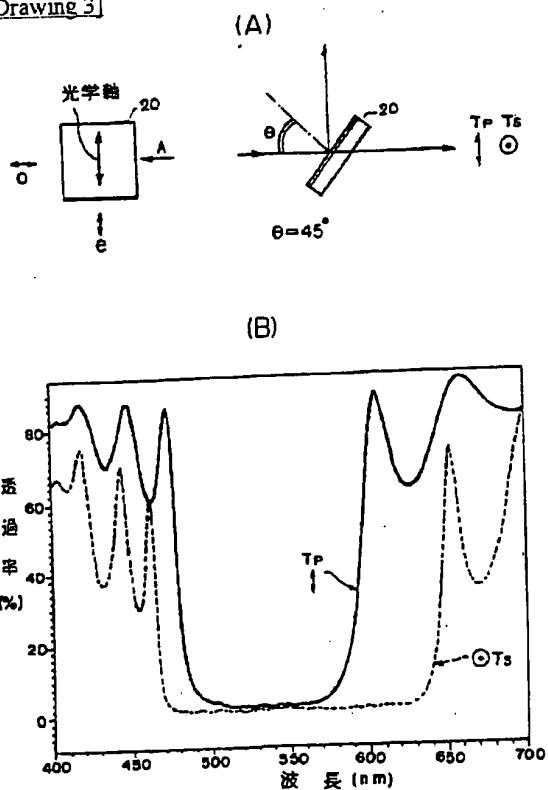
[Drawing 1]



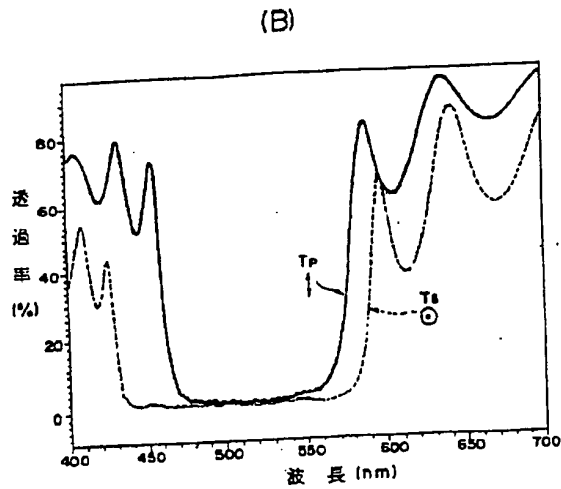
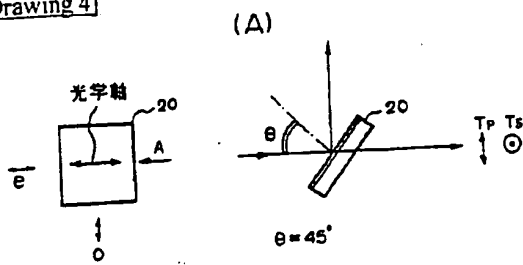
[Drawing 2]



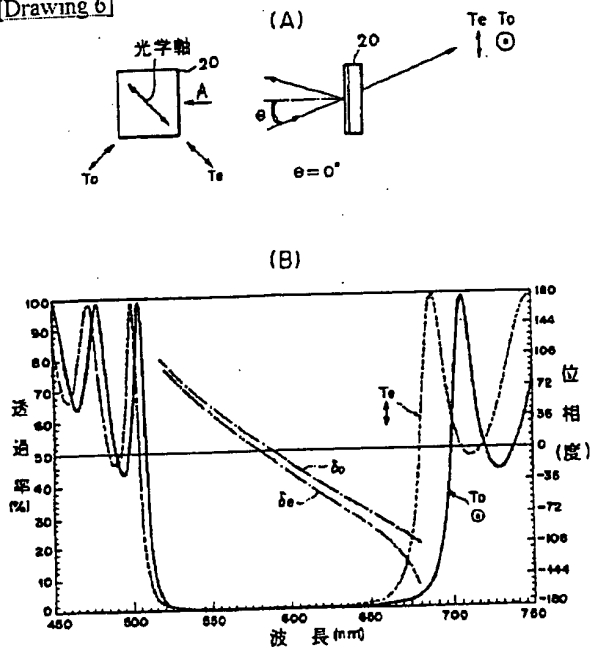
[Drawing 3]



[Drawing 4]

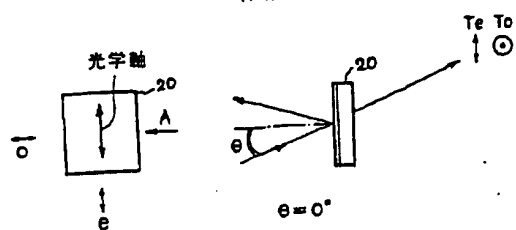


[Drawing 6]

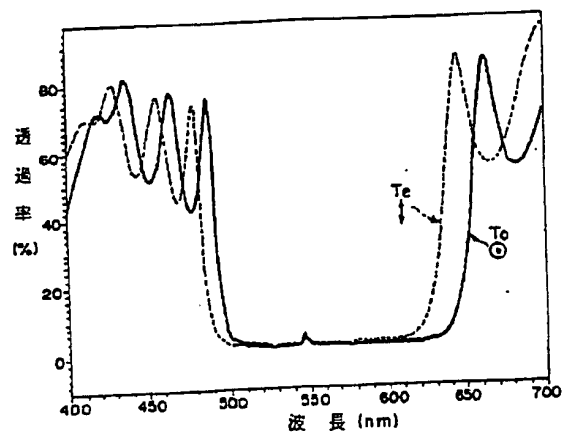


[Drawing 5]

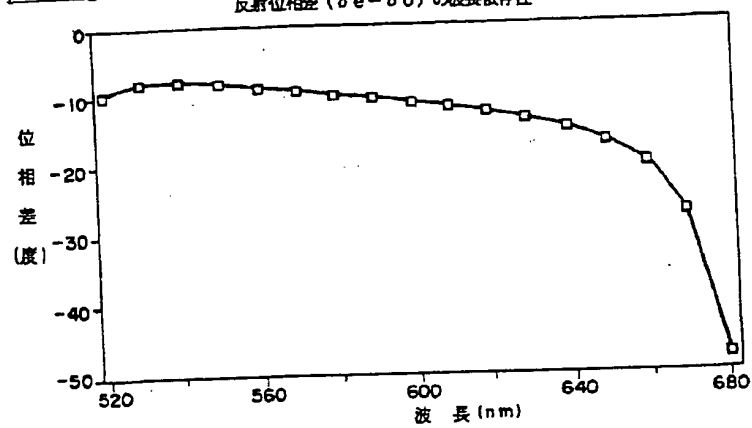
(A)



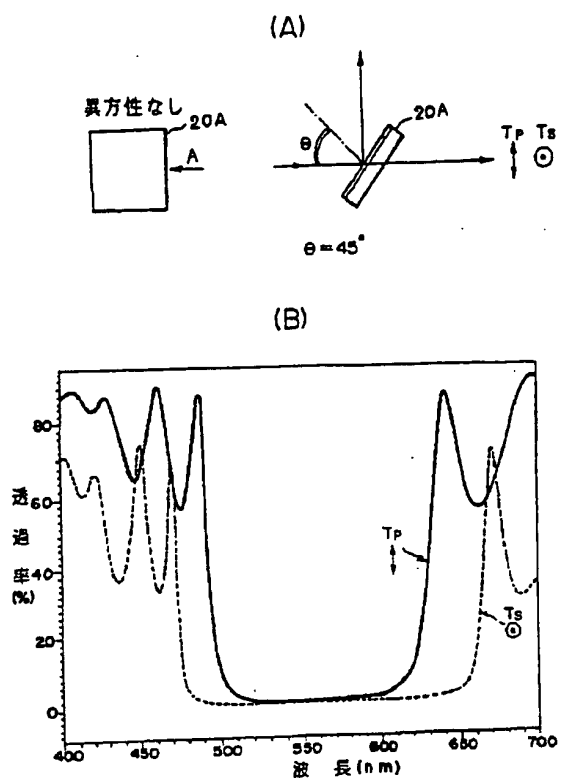
(B)



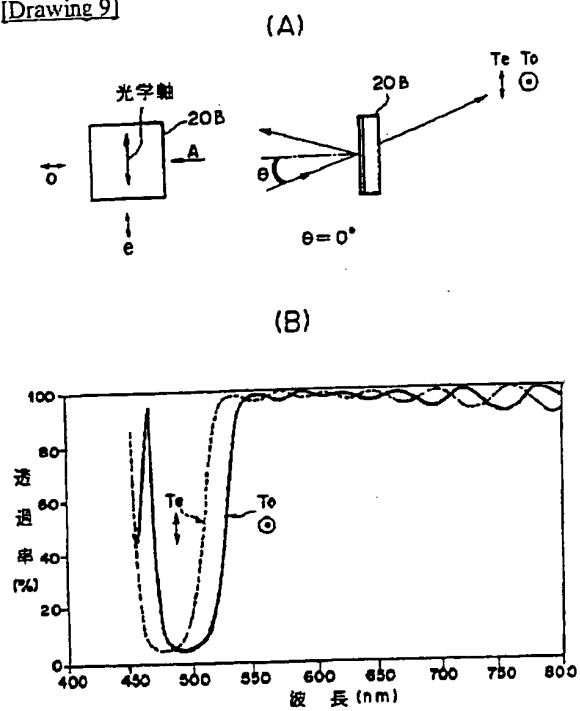
[Drawing 7]

反射位相差 ($\delta_e - \delta_o$) の波長依存性

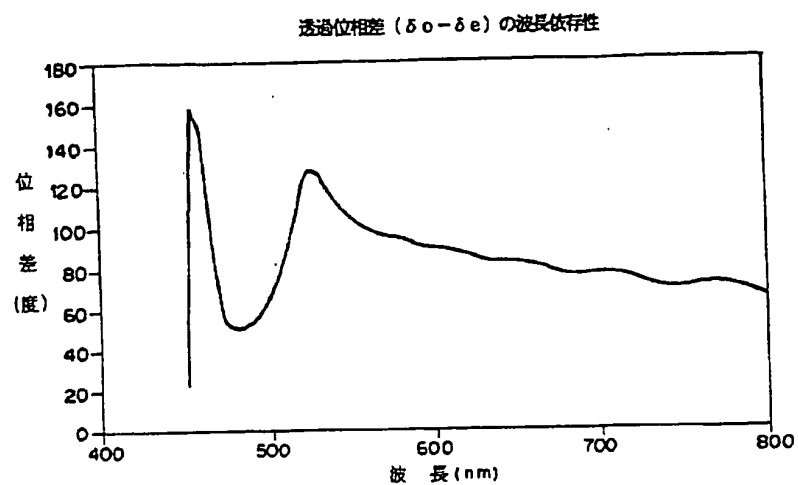
[Drawing 8]



[Drawing 9]



[Drawing 10]



[Translation done.]

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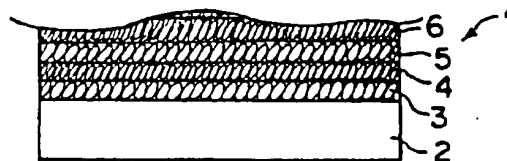
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(54) 【発明の名称】 複屈折板およびこれを用いた光学系

(57) 【要約】

【目的】 互いに異なる所定の複数の誘電体材料からなる斜め蒸着単層膜を交互に積層してなる斜め蒸着膜により複屈折性を持たせ、各種光学要素として用いる場合にその光学設計の自由度を高める。

【構成】 この複屈折板1は、透明ガラス基板2上にTiO₂ (二酸化チタン) の単層膜3、5とSiO₂ (酸化ケイ素) の単層膜4、6を交互に斜め蒸着により形成してなる。図1には、省略して描かれているが、実際には2層の単層膜が積層されている。また、各単層膜3、4、5、6の膜厚は略λ/4 (λ=650nm) に設定されている。



【特許請求の範囲】

【請求項1】被蒸着基板の表面上に斜め方向から誘電体材料を蒸着せしめて斜め蒸着膜を形成してなる複屈折板において、

該斜め蒸着膜は、互いに異なる誘電体材料からなる斜め蒸着単層膜を交互に積層してなることを特徴とする複屈折板。

【請求項2】前記斜め蒸着膜を構成する全ての斜め蒸着単層膜の光学軸が略同一方向とされていることを特徴とする請求項1記載の複屈折板。

【請求項3】請求項2の複屈折板を用いた光学系において、

該複屈折板に照射された光ビームがこの複屈折板から射出された後に所定の複屈折量を有するように、この複屈折板に入射する光ビームの入射面と前記光学軸とが所定の角度関係となるよう複屈折板を配設してなることを特徴とする複屈折板を用いた光学系。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、各種光学機器に用いられる、斜め蒸着膜が形成された複屈折板およびこの複屈折板を用いた光学系に関するものである。

【0002】

【従来の技術】従来より、基板表面に誘電体材料の斜め蒸着膜を形成した複屈折板が知られている。これは、蒸着材料（誘電体材料）の飛来方向に対して基板表面を傾斜させて配置し、基板表面から斜め方向に成長する柱状組織として蒸着膜を形成することにより、該蒸着膜に、入射光に対する複屈折作用を付与せしめたものであり、例えば、偏光ビームスプリッタや位相板等の光学機能素子として利用されている。

【0003】

【発明が解決しようとする課題】ところで、上述した如き複屈折板においては、この複屈折板に入射する光の直交偏光成分間の位相差を自在に制御することが困難であった。したがって、例えば上記複屈折板を位相板として用いる場合には任意の位相差を得ることが難しかった。また、上記複屈折板を板状のビームスプリッタとして用いる場合には、複屈折量が小さいために小さい入射角で光ビームを入射させるように設計することは困難であった。

【0004】本発明はこのような事情に鑑みなされたものであり、斜め蒸着膜が形成されてなる複屈折板を光学システム中で各種光学要素として用いる場合に、その光学システムの設計の自由度を高めることができる複屈折板およびこれを用いた光学系を提供することを目的とするものである。

【0005】

【課題を解決するための手段】本発明の複屈折板は、被蒸着基板の表面上に斜め方向から誘電体材料を蒸着せし

めて斜め蒸着膜を形成してなる複屈折板において、該斜め蒸着膜は、互いに異なる誘電体材料からなる斜め蒸着単層膜を交互に積層してなることを特徴とするものである。また、前記斜め蒸着膜を構成する全ての斜め蒸着単層膜の光学軸が略同一方向とされていることが望ましい。

【0006】さらに、本発明の複屈折板を用いた光学系は、前記斜め蒸着膜を構成する全ての斜め蒸着単層膜の光学軸が略同一方向とされている上記複屈折板であって、該複屈折板に照射された光ビームがこの複屈折板から射出された後に所定の複屈折量を有するように、この複屈折板に入射する光ビームの入射面と前記光学軸とが所定の角度関係となるよう複屈折板を配設してなることを特徴とするものである。なお、上記「交互」とは2種類の単層膜のみならず3種類以上の単層膜を順に積み重ねていく状態をも意味するものとする。

【0007】

【発明の実施の形態】以下、本発明の一実施形態について図面を参照しながら説明する。図1は、本発明の一実施形態の複屈折板を示す概略図である。なお、図1において、積層方向のスケールは実際のスケールとは異なるスケールで描かれている。この複屈折板1は、透明ガラス基板2上にTiO₂（二酸化チタン）の単層膜3、5とSiO₂（酸化ケイ素）の単層膜4、6を交互に斜め蒸着により形成してなる。なお、この透明ガラス基板に代えて種々の材料よりなる基板を用いることが可能である。

【0008】図1では、省略して描かれているが、実際には多数の、例えば22層の単層膜が積層されている。また、各単層膜3、4、5、6の膜厚は略 $\lambda/4$ （ $\lambda=650\text{nm}$ ）に設定されている。この図1に示す複屈折板1は例えば図2（A）に示す如き蒸着装置により形成される。

【0009】この蒸着装置は、図示しない排気ポンプにより内部を真空に排気されるベルジャー11と、TiO₂とSiO₂の蒸着材料12A、12Bを蒸発させるための蒸発源12と、この蒸発源12の各蒸着材料12A、12Bを加熱するための電子ビーム13Aを射出する電子銃13と、蒸発源12から蒸発した蒸着流14が基板16の表面に対し斜めに入射するように複数の基板16を所定の角度位置に設定保持するドーム状ワーク15等を備えている。このドーム状ワーク15は、図示されない回転モータにより所定方向に所定速度で回転可能とされており、これにより保持された基板16間および各基板16上において膜厚の均一化が図られる。なお、蒸発源12はこのドーム状ワーク15の回転軸下方の近傍に配設されている。

【0010】また、図2（B）は、図2（A）のドーム状ワーク15を上方から見た図である。各基板16は図示されない所定の基板ホルダによってドームの内壁部に

取り付けられる。なお、本図においては、保持される基板16の一部のみが描かれているが、実際には中心位置から全周囲方向に多数の基板16が配列されるようにして保持される。また、上記蒸着流14の基板16表面への入射角 α （実際は基板16の法線と鉛直方向のなす角度；以下同じ）は特に限定されるものではないが、平均値で $45^\circ \sim 65^\circ$ 程度とすれば、複屈折量（常光に対する屈折率 n_o と異常光に対する屈折率 n_e の差 Δn ）を大きい値としつつ蒸着膜の白濁化を防止することが可能である。

【0011】なお、上記実施形態では、誘電体材料として TiO_2 および SiO_2 を用いているが、本発明で用いられる誘電体材料としては、基本的には使用する光に対して透明であり、かつその材料の組み合わせにより所望の複屈折量が得られればよく、例えば、 Ta_2O_5 、 Al_2O_3 、 WO_3 、 Y_2O_3 、 Bi_2O_3 、 Nb_2O_5 、 ZnS 、 MoO_3 、 CeO_2 、 SiO 、 SnO_2 等の金属酸化物を用いることができる。また、蒸着膜の厚みとしては上記実施例のものに限られるものではなく、種々の厚とすることが可能であるが、各層について柱状組織が十分に成長することができる程度の厚みとすることが望ましく、例えば数十nm以上とすることが望ましい。

【0012】また、3種類以上の単層膜を順に繰り返して積層させるようにすることも可能である。また、1つの複屈折板16においては、各蒸着膜3、4、5、6における光学軸も略そろえられており、この複屈折板16を使用する際に、この光学軸の方向と光入射面の角度関係および入射角 θ の値を適切に調整することにより、所望の偏光透過率、偏光反射率を得ることができ、かつ、入射光の直交する偏光成分間の位相差を所望の値とすることができ、光学系を得ることが可能である。

【0013】

【実施例】以下、具体的な実施例について説明する。

【0014】＜実施例1＞蒸着流14の基板16への入射角 α を 60° に設定し、膜厚が $\lambda/4$ （ $\lambda=650\text{nm}$ ）に設定された TiO_2 と SiO_2 の交互層を可視光に対して透明なガラス基板2上に22層積層し、偏光ビームスプリッタ20を形成した。次に、この偏光ビームスプリッタ20の成膜表面に対し、光ビームの入射角度 θ が 45° となるように、かつ、光入射面と光学軸が平行となるように光ビームを入射させた（図3（A））。なお、図3（A）の右図は、図3（A）の左図の矢印A方向から見たときの側面図である。このときのP成分の光透過率 T_p とS成分の光透過率 T_s の分光特性を図3（B）に示す。

【0015】＜実施例2＞上記実施例1と同様にして形成された偏光ビームスプリッタ20の成膜表面に対し、光ビームの入射角度 θ が 45° となるように、かつ、光入射面と光学軸が直交するように光ビームを入射させた（図4（A））。なお、図4（A）の右図は、図4

（A）の左図の矢印A方向から見たときの側面図である。このときのP成分の光透過率 T_p とS成分の光透過率 T_s の分光特性を図4（B）に示す。

【0016】＜実施例3＞上記実施例1と同様にして形成された偏光ビームスプリッタ20の成膜表面に対し、光ビームの入射角度 θ が 0° となるように光ビームを入射させた（図5（A））。なお、図5（A）の右図は、図5（A）の左図の矢印A方向から見たときの側面図である。このときの常光の方向での偏光透過率 T_o と異常光の方向での偏光透過率 T_e の分光特性を図5（B）に示す。また、このときの常光の方向での反射位相 δ_o と異常光の方向での反射位相 δ_e の値を図6（B）に示す。なお、図6（A）に示す光学素子配置、および図6（B）の T_o と T_e の分光特性を示すグラフは、各々図5（A）に示す光学素子配置、および図5（B）の T_o と T_e の分光特性を示すグラフと実質的に略同じである。また、図7は上記2つの反射位相 δ_o 、 δ_e の差の波長依存性を示すグラフである。

【0017】＜比較例＞蒸着流14の基板16への入射角 α を 0° に設定し、膜厚が $\lambda/4$ （ $\lambda=650\text{nm}$ ）に設定された TiO_2 と SiO_2 の交互層を可視光に対して透明なガラス基板2上に22層積層し、複屈折性を有しないビームスプリッタ20Aを形成した。このビームスプリッタ20Aの成膜表面に対し、光ビームの入射角度 θ が 45° となるように光ビームを入射させた（図8（A））。なお、図8（A）の右図は、図8（A）の左図の矢印A方向から見たときの側面図である。このときのP成分の光透過率 T_p とS成分の光透過率 T_s の分光特性を図8（B）に示す。

【0018】上記実施例1と実施例2のものを比較例のものと比較して見ると、それらの分光特性を示すグラフからも明らかなように T_p と T_s の立ち上がり波長の間隔が狭くなっている。また、複屈折性を有しないものでは入射角 $\theta=0^\circ$ とした場合には偏光特性を有しないことから、これと比べて実施例3のものが大きく異なっているのが明らかである。

【0019】なお、図6および図7においては反射の位相 δ_o 、 δ_e に関する数値を示しているが、もちろん透過の位相も同様にして示すことが可能（図10参照）であり、これにより、光学系の設計の自由度が大きくなる。さらに、入射角 θ が 0° 以外となる場合には、P成分の位相 δ_p およびS成分の位相 δ_s をも考慮に入れて光学系の設計を行うことができる。

【0020】＜実施例4＞蒸着流14の基板16への入射角 α を 60° に設定し、膜厚が下記表1の如く設定された TiO_2 （複屈折量 $\Delta n=0.075$ ）と Ta_2O_5 （複屈折量 $\Delta n=0.065$ ）の交互層を、可視光に対して透明なガラス基板2上に35層積層し、さらに膜厚が下記表1の如く設定された SiO_2 （複屈折量 $\Delta n \approx 0$ ）よりなる最上層を形成して位相板20Bを作製した。このときの全膜厚は

2.064nmであった。この位相板20Bを図9(A)に示す如く配置し、波長 λ_0 が600nmの光ビームをこの位相板20Bの成膜表面に対して入射角 θ が0°となるように光ビームを入射させた(図9(A))。なお、図9(A)の右図は、図9(A)の左図の矢印A方向から見た時の側面図である。

【0021】このような状態に配設された位相板20Bは、波長 λ_0 が600nmの光ビームに対し、直交する偏光成分の位相を互いに88°ずらすことができ、 λ_0

4板として機能する。このときの常光の方向での偏光透過率 T_o と異常光の方向での偏光透過率 T_e の分光特性を図9(B)に示す。また、このときの常光の方向での透過位相 δ_o と異常光の方向での透過位相 δ_e の差の波長依存性を表すグラフを図10に示す。下記表1に、本実施例の具体的な膜構成を示す。

【0022】

【表1】

膜No.	材料	屈折率 n_o	膜厚 d (nm)	$4\pi n_o d / \lambda_0$
	空気	1.0		
1	SiO ₂	1.46	89.5	1.045
2	TiO ₂	2.3	39.5	0.727
3	Ta ₂ O ₅	2.0	50.0	0.800
4	TiO ₂	2.3	48.9	0.900
5	Ta ₂ O ₅	2.0	62.5	1.000
6	TiO ₂	2.3	54.3	1.000
7	Ta ₂ O ₅	2.0	62.5	1.000
8	TiO ₂	2.3	54.3	1.000
9	Ta ₂ O ₅	2.0	62.5	1.000
10	TiO ₂	2.3	54.3	1.000
11	Ta ₂ O ₅	2.0	62.5	1.000
12	TiO ₂	2.3	54.3	1.000
13	Ta ₂ O ₅	2.0	62.5	1.000
14	TiO ₂	2.3	54.3	1.000
15	Ta ₂ O ₅	2.0	62.5	1.000
16	TiO ₂	2.3	54.3	1.000
17	Ta ₂ O ₅	2.0	62.5	1.000
18	TiO ₂	2.3	54.3	1.000
19	Ta ₂ O ₅	2.0	62.5	1.000
20	TiO ₂	2.3	54.3	1.000
21	Ta ₂ O ₅	2.0	62.5	1.000
22	TiO ₂	2.3	54.3	1.000
23	Ta ₂ O ₅	2.0	62.5	1.000
24	TiO ₂	2.3	54.3	1.000
25	Ta ₂ O ₅	2.0	62.5	1.000
26	TiO ₂	2.3	54.3	1.000
27	Ta ₂ O ₅	2.0	62.5	1.000
28	TiO ₂	2.3	54.3	1.000
29	Ta ₂ O ₅	2.0	62.5	1.000
30	TiO ₂	2.3	54.3	1.000
31	Ta ₂ O ₅	2.0	62.5	1.000
32	TiO ₂	2.3	54.3	1.000
33	Ta ₂ O ₅	2.0	62.5	1.000
34	TiO ₂	2.3	48.9	0.900
35	Ta ₂ O ₅	2.0	50.0	0.800
36	TiO ₂	2.3	39.5	0.727
全膜厚				約 2064
ガラス基板		1.51		
(BK7)				

但し、 $\lambda_0 = 500\text{nm}$

【0023】

【発明の効果】以上説明したように、本発明の複屈折板およびこれを用いた光学系によれば2種類以上の単層膜を交互に斜め蒸着せしめて、斜め蒸着膜を形成している。したがって、各単層膜を形成する誘電体材料、各単層膜の光学膜厚および層数をパラメータとして、所望の複屈折量のもので得ることができるので光学素子の設計自由度を高めることができる。また、各単層膜の光学軸の方向を略そらえておき、この光学素子を使用する際に、この光学軸の方向と光入射面との角度関係、および入射角度を適切に選択することにより光学素子ひいては光学システムの設計自由度をさらに高めることができる。

【0024】例えば、従来の偏光ビームスプリッタにおいては、小さい入射角で光ビームが入射する場合には、板状のビームスプリッタは使用できず、ガラスブロックタイプのビームスプリッタを使用しなければならなかったが、本発明のものを適用することにより、小さい入射角の光ビームに対しても板状のビームスプリッタで直交する2偏光成分を確実に分離することが可能となる。また、このビームスプリッタに位相板としての機能を持たせる設計とすることもできるので、従来ビームスプリッタにおいて、その後段の一方の光路上に設けられることがあった位相板（例えば $\lambda/4$ 板、 $\lambda/2$ 板）が不用となる。

【0025】また、例えば、カラー液晶ビデオプロジェクトのダイクロイックプリズムで各々の色情報を担持した偏光成分が合成される際に、従来のものではそれら各偏光成分の分光特性で立ち上がり波長の値に大きなずれが生じているため、合成後の分光特性が階段状となってしまうが、本発明を適用することにより上記2つの偏光成分の分光特性における立ち上がりの波長の値を極めて近い値に設定することができることから、これら2つの偏光成分を合成したときに合成分光特性が階段状となるのを防止することが可能である。なお、上記2つの偏光成分のうち一方の分光特性を変えることなく、他方の分

光特性を変えて、両者の間隔を拡げることも可能である。

【図面の簡単な説明】

【図1】本発明の実施形態に係る複屈折板の層構成を示す概略図

【図2】図1に示す複屈折板の斜め蒸着膜を形成する蒸着装置の一例を示す概略図

【図3】実施例1の光学素子配置図(A)および光透過率特性を示すグラフ(B)

【図4】実施例2の光学素子配置図(A)および光透過率特性を示すグラフ(B)

【図5】実施例3の光学素子配置図(A)および光透過率特性を示すグラフ(B)

【図6】実施例3の光学素子配置図(A)、および光透過率特性と反射位相を示すグラフ(B)

【図7】実施例3における反射位相の差を示すグラフ

【図8】比較例の光学素子配置図(A)および光透過率特性を示すグラフ(B)

【図9】実施例4の光学素子配置図(A)および光透過率特性を示すグラフ(B)

【図10】実施例4における透過位相の差を示すグラフ

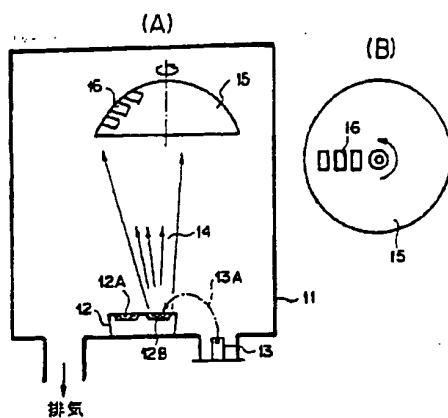
【符号の説明】

1	複屈折板
2	透明ガラス基板
3、4、5、6	単層膜
11	ベルジャー
12	蒸発源
12A、12B	蒸着材料
13	電子銃
13A	電子ビーム
14	蒸着流
15	ドーム状ワーク
16	基板
20、20A	ビームスプリッタ
20B	位相板

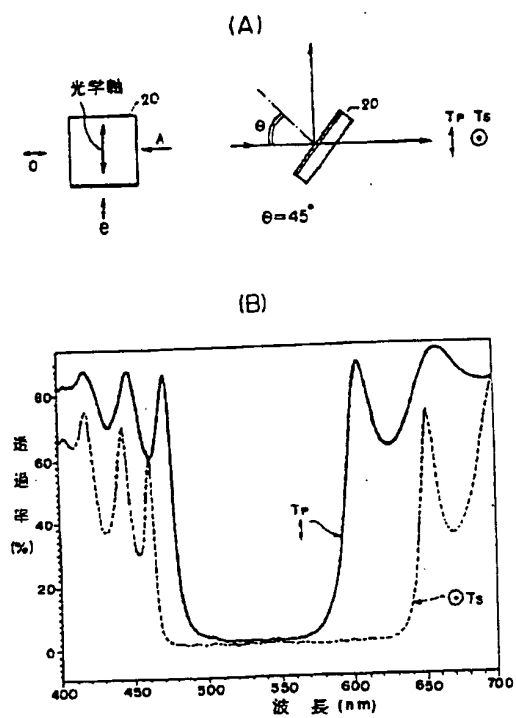
【図1】



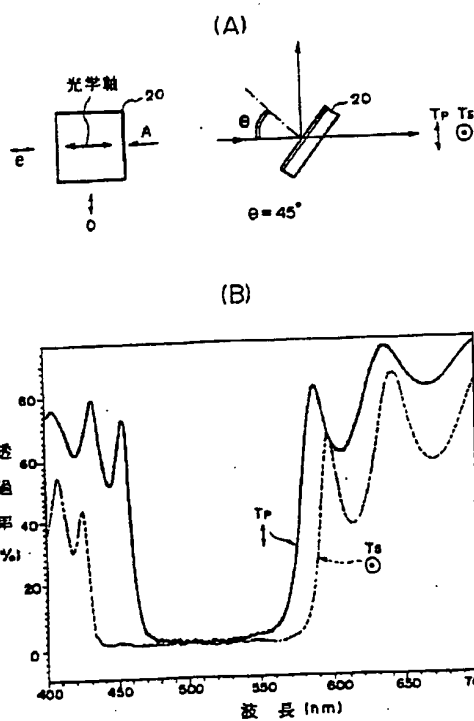
【図2】



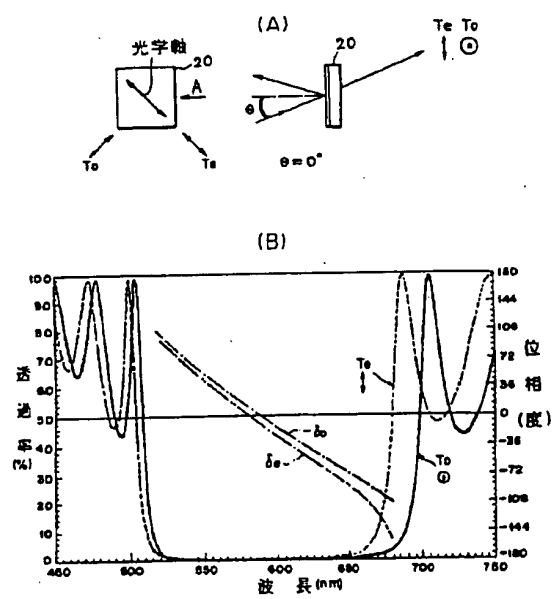
【図3】



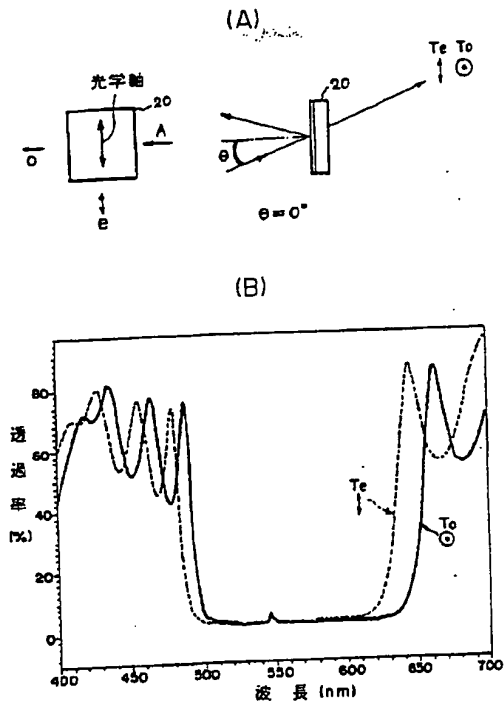
【図4】



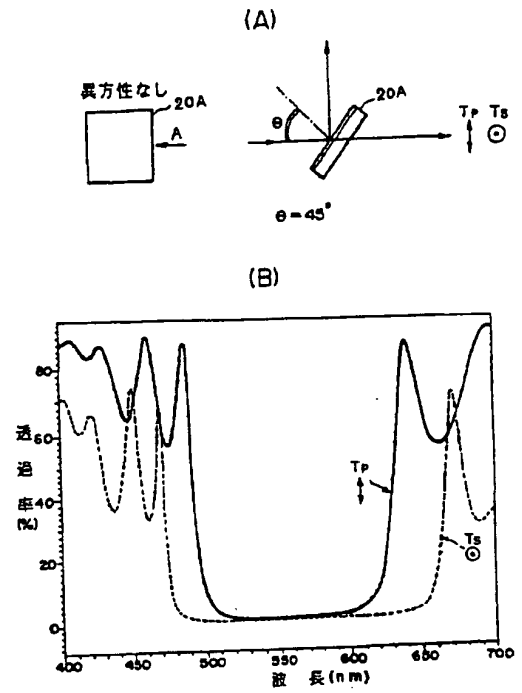
【図6】



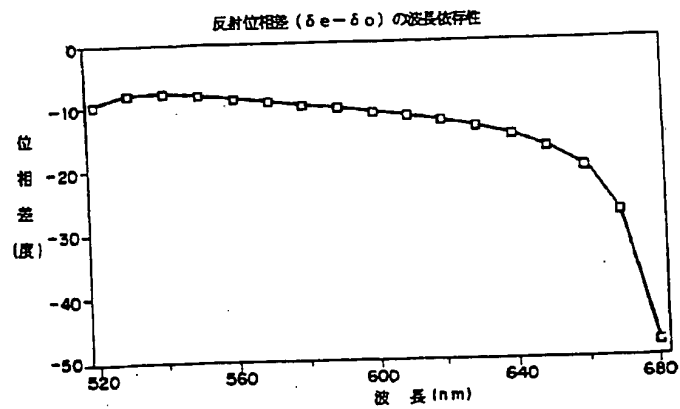
【図5】



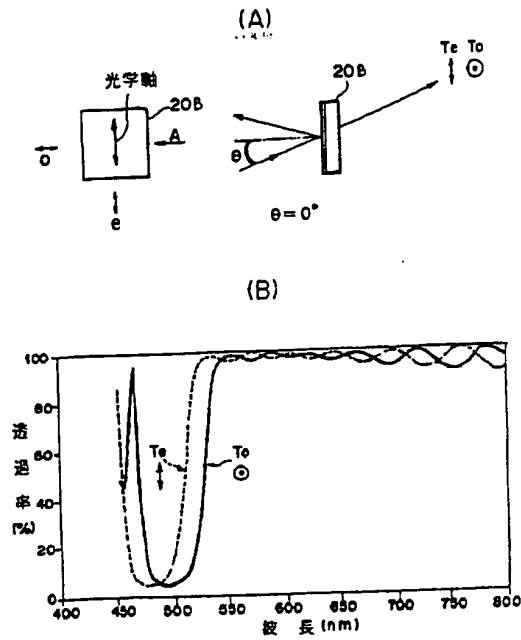
【図8】



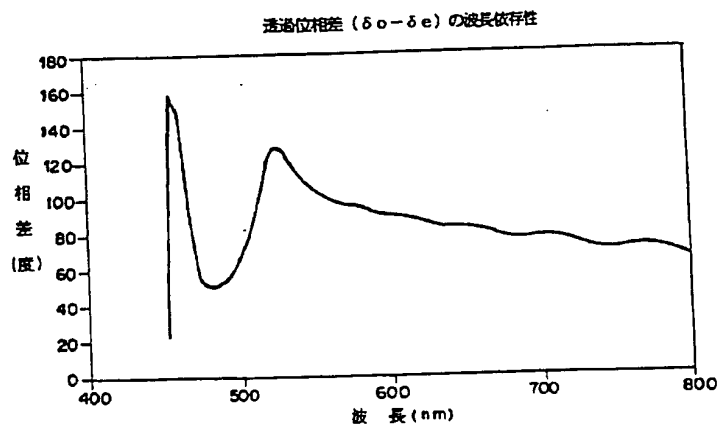
【図7】



【図9】



【図10】



【手続補正書】

【提出日】平成8年1月30日

【手続補正1】

【補正対象書類名】明細書

【補正対象項目名】0022

【補正方法】変更

【補正内容】

【0022】

【表1】

膜No.	材料	屈折率 n_0	膜厚 d (nm)	$4n_0d/\lambda_0$
	空気	1. 0		
1	SiO ₂	1. 46	89. 5	1. 045
2	TiO ₂	2. 3	39. 5	0. 727
3	Ta ₂ O ₅	2. 0	50. 0	0. 800
4	TiO ₂	2. 3	48. 9	0. 900
5	Ta ₂ O ₅	2. 0	62. 5	1. 000
6	TiO ₂	2. 3	54. 3	1. 000
7	Ta ₂ O ₅	2. 0	62. 5	1. 000
8	TiO ₂	2. 3	54. 3	1. 000
9	Ta ₂ O ₅	2. 0	62. 5	1. 000
10	TiO ₂	2. 3	54. 3	1. 000
11	Ta ₂ O ₅	2. 0	62. 5	1. 000
12	TiO ₂	2. 3	54. 3	1. 000
13	Ta ₂ O ₅	2. 0	62. 5	1. 000
14	TiO ₂	2. 3	54. 3	1. 000
15	Ta ₂ O ₅	2. 0	62. 5	1. 000
16	TiO ₂	2. 3	54. 3	1. 000
17	Ta ₂ O ₅	2. 0	62. 5	1. 000
18	TiO ₂	2. 3	54. 3	1. 000
19	Ta ₂ O ₅	2. 0	62. 5	1. 000
20	TiO ₂	2. 3	54. 3	1. 000
21	Ta ₂ O ₅	2. 0	62. 5	1. 000
22	TiO ₂	2. 3	54. 3	1. 000
23	Ta ₂ O ₅	2. 0	62. 5	1. 000
24	TiO ₂	2. 3	54. 3	1. 000
25	Ta ₂ O ₅	2. 0	62. 5	1. 000
26	TiO ₂	2. 3	54. 3	1. 000
27	Ta ₂ O ₅	2. 0	62. 5	1. 000
28	TiO ₂	2. 3	54. 3	1. 000
29	Ta ₂ O ₅	2. 0	62. 5	1. 000
30	TiO ₂	2. 3	54. 3	1. 000
31	Ta ₂ O ₅	2. 0	62. 5	1. 000
32	TiO ₂	2. 3	54. 3	1. 000
33	Ta ₂ O ₅	2. 0	62. 5	1. 000
34	TiO ₂	2. 3	48. 9	0. 900
35	Ta ₂ O ₅	2. 0	50. 0	0. 800
36	TiO ₂	2. 3	39. 5	0. 727
全膜厚			約 2064	
	ガラス基板 (BK7)	1. 51		

但し、 $\lambda_0=500\text{nm}$

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